SAMPLE DESIGN REPORT

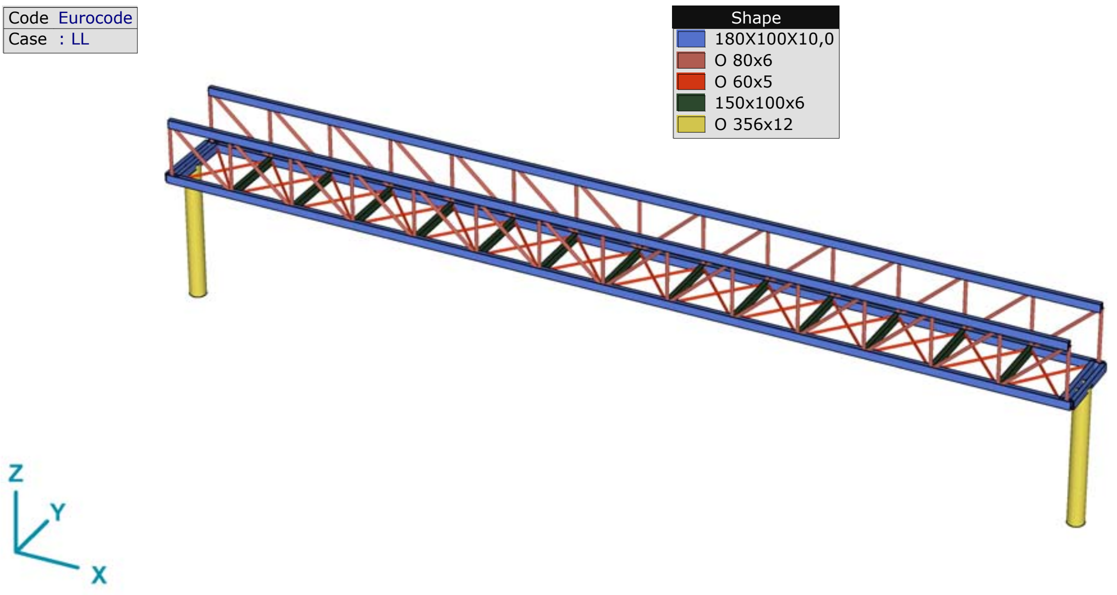
Pedestrian Bridge

Compressed chord buckling

2021.01.23

Prepared by:

[Your name here] [your title here] ……………………………………………



Rendered view

Input parameters

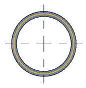
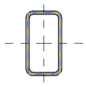
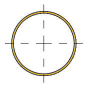
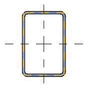
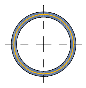
Materials

	Name	*Type*	*National design code*	*Material code*	*Model*	*E_x [kN/cm^2]*	*E_y [kN/cm^2]*
1	S 235	Steel	Eurocode-H	10025-2	Linear	21000	21000

	Name	*ν*	*α_T [1/°C]*	*ρ [kg/m^3]*	*Material color*	*Contour color*	*Texture*	*P_1*	*P_2*
1	S 235	0,30	1,2E-5	7850			Steel	f_y[N/mm^2] = 235,0	f_u[N/mm^2] = 360,0

	Name	*P_3*	*P_4*	*P_5*	*P_6*	*P_7*	*P_8*	*P_9*	*P_{10}*	*P_{11}*	*P_{12}*	*P_{13}*	*P_{14}*
1	S 235	f_y^*[N/mm^2] = 215,0	f_u^*[N/mm^2] = 360,0										

Cross-sections

	Name	*Drawing*	*Process*	*Shape*	*h [mm]*	*b [mm]*	*tw [mm]*	*tf [mm]*	r_1 *[mm]*	r_2 *[mm]*	r_3 *[mm]*
1	O 80x6		Cold f.	Pipe	80,0	80,0	6,3	6,3	0	0	0
2	180X100X10,0		Rolled	Box	180,0	100,0	10,0	10,0	20,0	0	0
3	O 356x12		Cold f.	Pipe	355,6	355,6	12,0	12,0	0	0	0
4	150x100x6		Rolled	Box	150,0	100,0	6,0	6,0	12,0	0	0
5	O 60x5		Cold f.	Pipe	60,0	60,0	5,0	5,0	0	0	0

	Name	*Ax* $[cm^2]$	*Ay* $[cm^2]$	*Az* $[cm^2]$	*Ix* $[cm^4]$	*Iy* $[cm^4]$	*Iz* $[cm^4]$	*Iyz* $[cm^4]$	I_1 $[cm^4]$	I_2 $[cm^4]$	*α [°]*
1	O 80x6	14,58	7,38	7,38	199,3	99,7	99,7	0	99,7	99,7	0
2	180X100X10,0	49,42	12,89	31,40	1868,5	1929,5	757,9	0	1929,5	757,9	0
3	O 356x12	129,51	64,88	64,89	38266,6	19131,7	19131,7	0	19131,7	19131,7	0
4	150x100x6	27,63	8,57	15,64	951,4	834,7	444,2	0	834,7	444,2	0
5	O 60x5	8,64	4,38	4,38	65,8	32,9	32,9	0	32,9	32,9	0

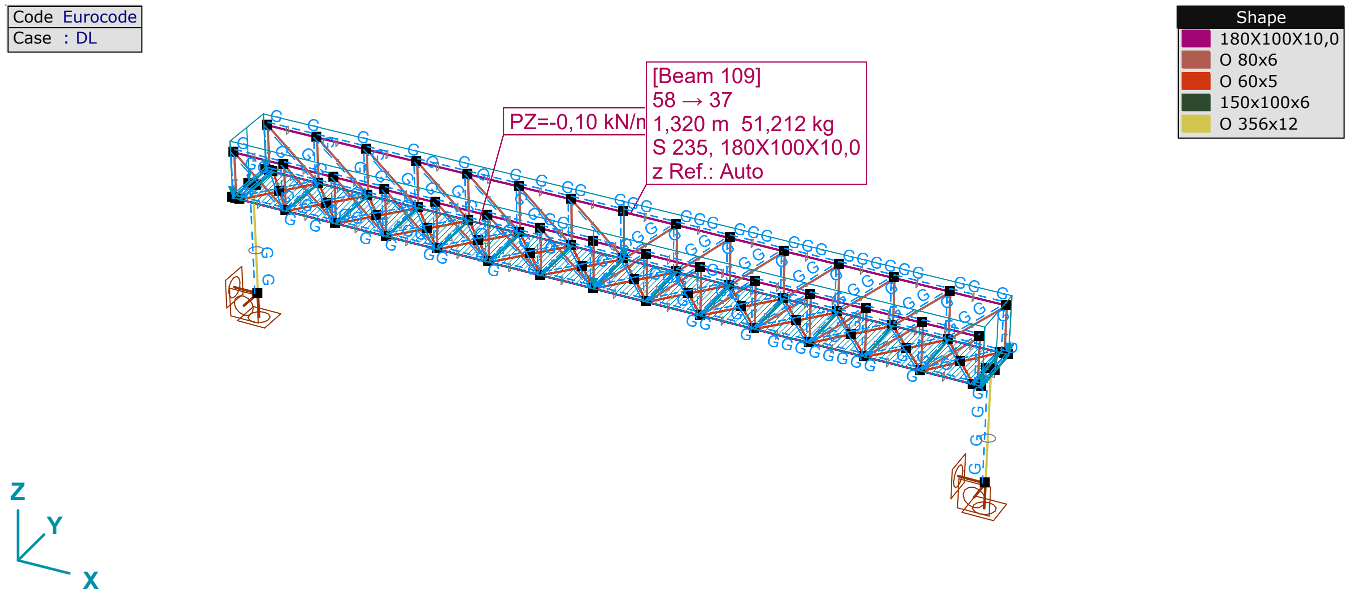
	Name	*Iω* $[cm^6]$	$W_{1,el,t}$ $[cm^3]$	$W_{1,el,b}$ $[cm^3]$	$W_{2,el,t}$ $[cm^3]$	$W_{2,el,b}$ $[cm^3]$	$W_{1,pl}$ $[cm^3]$	$W_{2,pl}$ $[cm^3]$	i_y *[mm]*	i_z *[mm]*	*Hy [mm]*	*Hz [mm]*
1	O 80x6	0	24,9	24,9	24,9	24,9	34,3	34,3	26,1	26,1	80,0	80,0
2	180X100X10,0	2492	214,4	214,4	151,6	151,6	275,3	181,6	62,5	39,2	100,0	180,0
3	O 356x12	0	1076,0	1076,0	1076,0	1076,0	1416,9	1416,9	121,5	121,5	355,6	355,6
4	150x100x6	509	111,3	111,3	88,8	88,8	136,7	103,3	55,0	40,1	100,0	150,0
5	O 60x5	0	11,0	11,0	11,0	11,0	15,2	15,2	19,5	19,5	60,0	60,0

	Name	y_G *[mm]*	z_G *[mm]*	y_s *[mm]*	z_s *[mm]*	*S.p.*
1	O 80x6	40,0	40,0	0	0	5
2	180X100X10,0	50,0	90,0	0	0	9
3	O 356x12	177,8	177,8	0	0	5
4	150x100x6	50,0	75,0	0	0	9
5	O 60x5	30,0	30,0	0	0	5

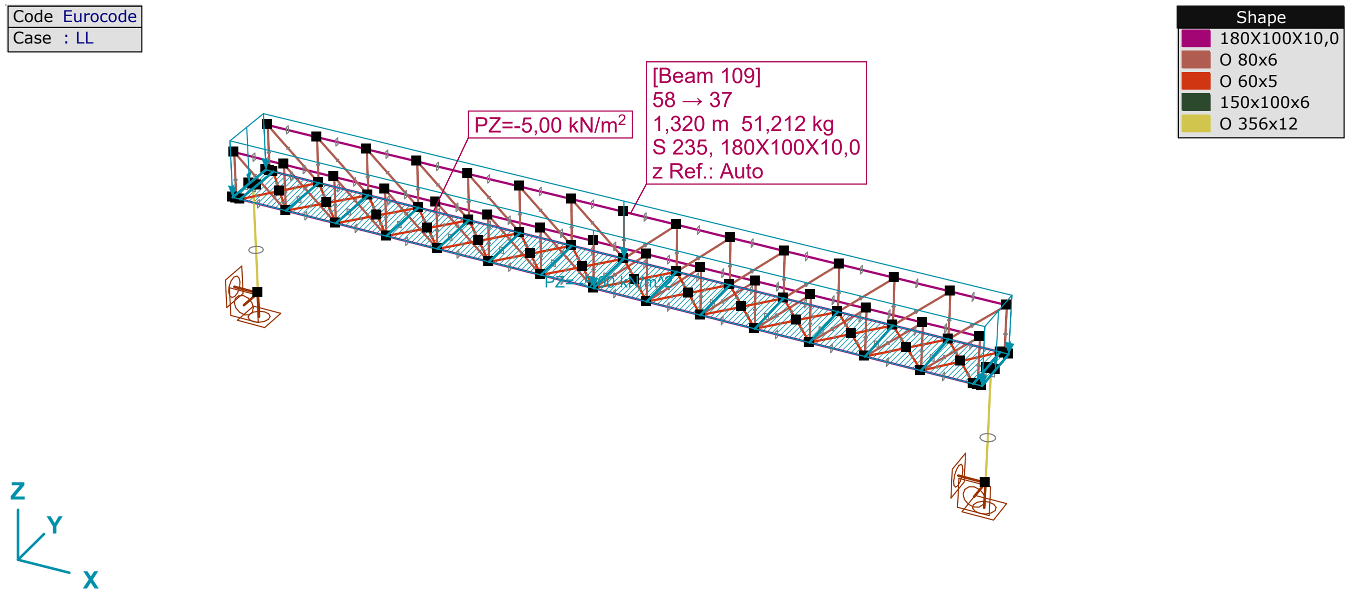
Weights per material

	Material name	*ρ* $[kg/m^3]$	*Σ V* $[m^3]$	*Σ G [kg]*
1	S 235	7850	0,699	5490,381
	Total		**0,699**	**5490,381**

Loads



Dead load



Live load

Load combinations

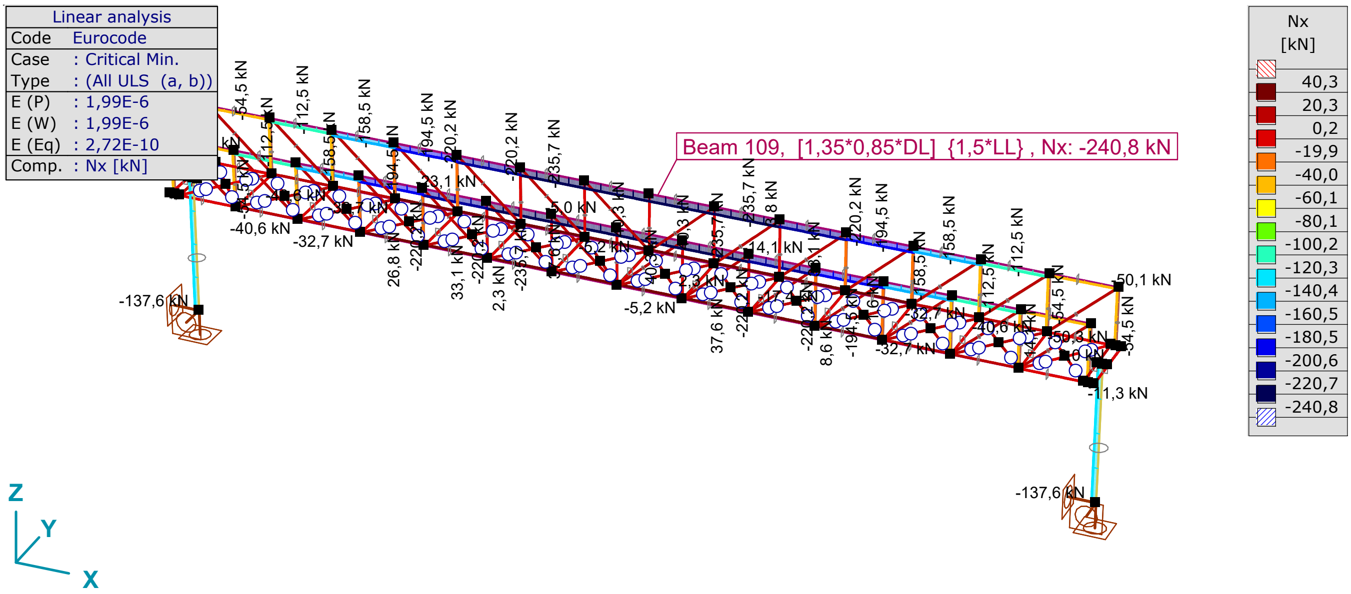
Calculated critical combinations by load cases

	Critical combination	*Type*
1	[DL]	ULS (a, b)
2	[DL] {1,05*LL}	ULS (a, b)
3	[1,35*DL]	ULS (a, b)
4	[1,35*DL] {1,05*LL}	ULS (a, b)
5	[DL] {1,5*LL}	ULS (a, b)
6	[1,15*DL]	ULS (a, b)
7	[1,15*DL] {1,5*LL}	ULS (a, b)
8	[DL]	SLS Characteristic
9	[DL] {LL}	SLS Characteristic
10	[DL]	SLS Frequent
11	[DL] {0,5*LL}	SLS Frequent

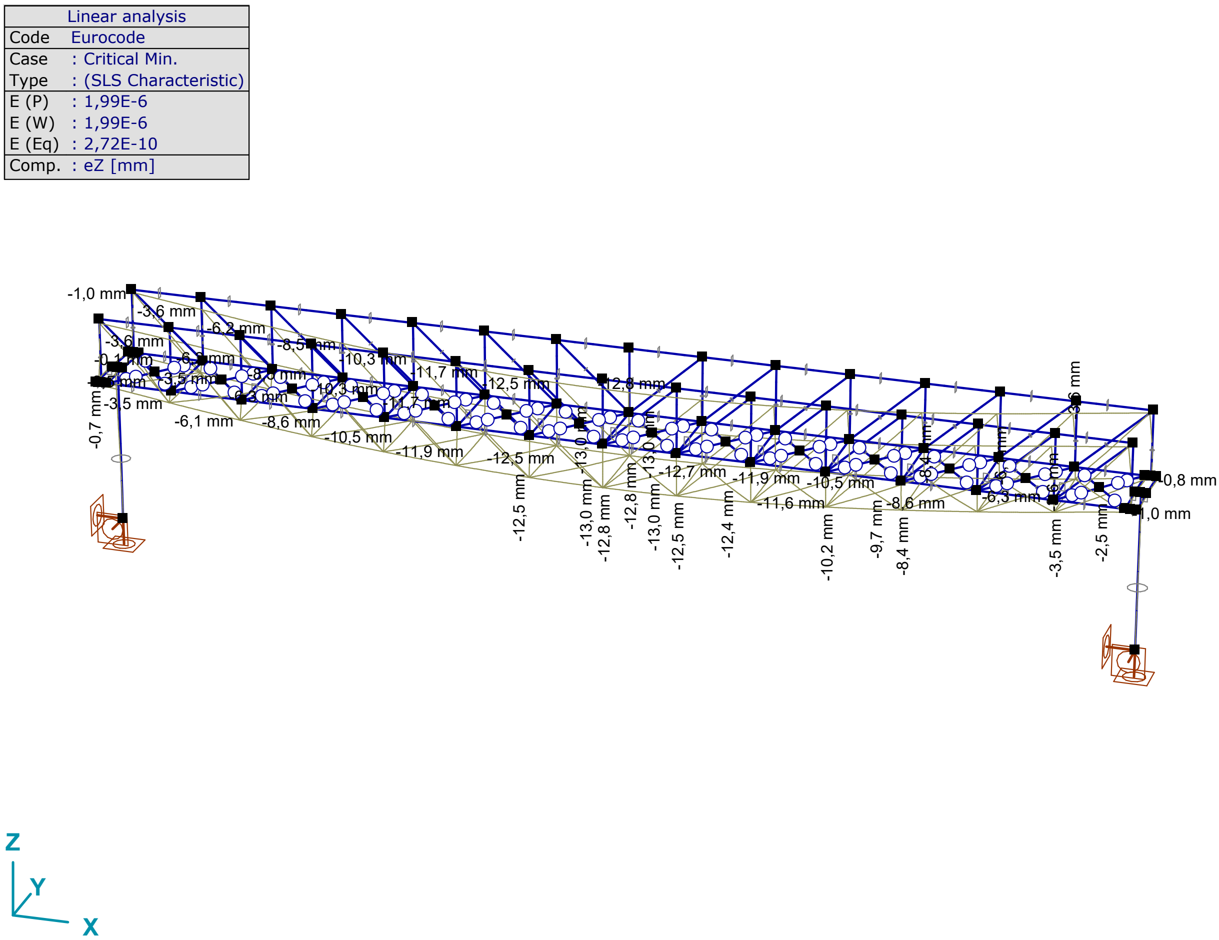
	Critical combination	*Type*
12	[DL]	SLS Quasipermanent
13	[DL] (0,3*LL)	SLS Quasipermanent
14	[DL]	A1(a,b)
15	[DL] {1,05*LL}	A1(a,b)
16	[1,35*DL]	A1(a,b)
17	[1,35*DL] {1,05*LL}	A1(a,b)
18	[DL] {1,5*LL}	A1(a,b)
19	[1,15*DL]	A1(a,b)
20	[1,15*DL] {1,5*LL}	A1(a,b)
21	[DL]	A2(a,b)
22	[DL] {1,3*LL}	A2(a,b)

General results

Only normal force and deflection is listed here, the report focuses on buckling results.



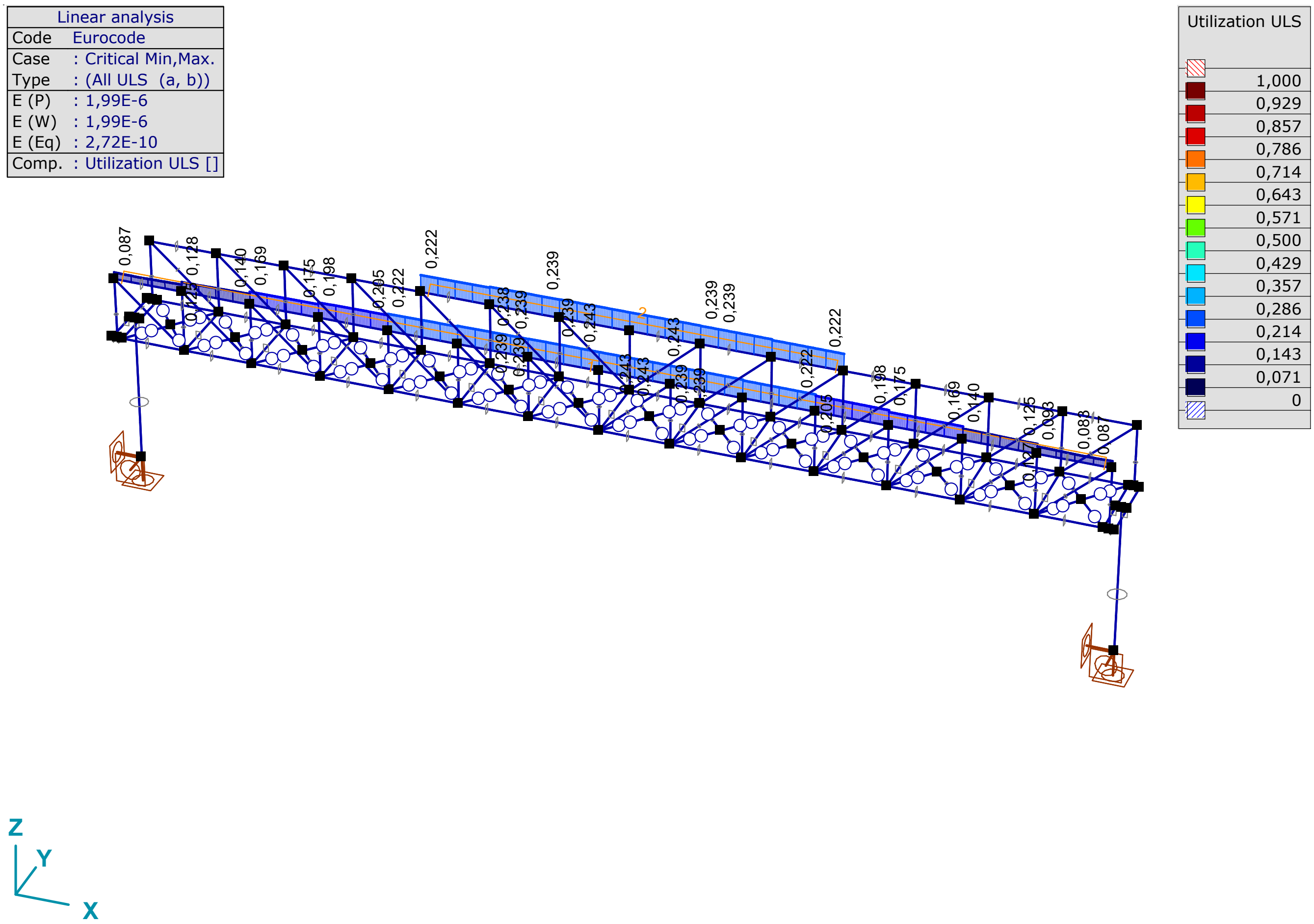
[I], Linear,(Auto) Critical Min., Nx [kN], Filled diagram



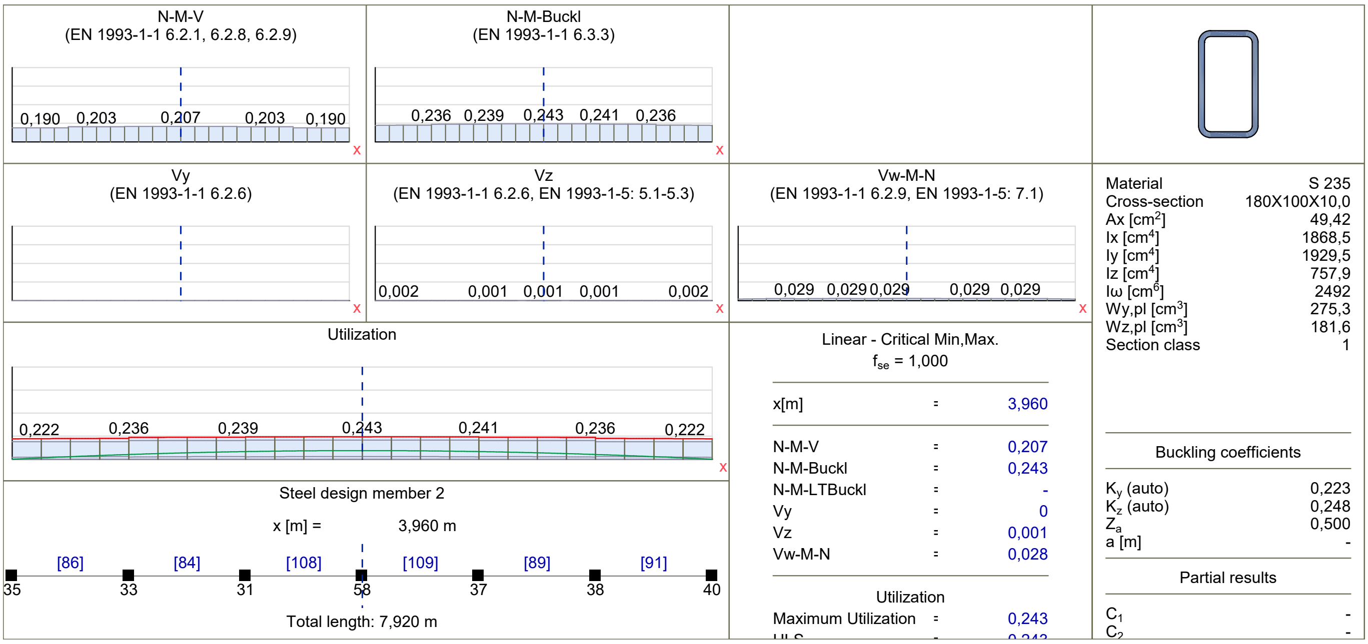
[I], Linear,(Auto) Critical Min., eZ [mm], Diagram

Design of compressed steel chord

Design is carried out using AxisVM's built-in steel design module, it does not use or require the separate buckling analysis. See reference of automated calculation of buckling coefficients in the software manual.



[Stl], Linear,(Auto) Critical, Utilization ULS [], Filled diagram



[Stl], Linear,(Auto) Critical, Utilization, Steel design member 2, [Pos.: 3,960m;]

STEEL MEMBER DESIGN

Design member **2**

Nodes: **35-40**

Code: **Eurocode**

EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006

Material: **S 235**

Cross-section: **180X100X10,0**

Load case: **Linear,(Auto) Critical**

Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}33 \cdot L = 0{,}33 \cdot 7920{,}00 = 2640{,}00$ mm

$N_{Ed_1} = -240791{,}50$ N $V_{y,Ed_1} = 0{,}61$ N $V_{z,Ed_1} = -407{,}79$ N $M_{y,Ed_1} = -1671151{,}40$ Nmm $= -1{,}67$ kNm $M_{z,Ed_1} =$ $= 12069{,}61$ Nmm $= 0{,}01$ kNm $M_{x,Ed_1} = 8980{,}90$ Nmm $= 0{,}01$ kNm

$\eta_{NMV_{pl}} = \max\left(\eta_N ; \eta_{M_{y,pl}} ; \eta_{M_{z,pl}} ; \eta_{V_z} ; \eta_{V_y}\right) = \max(20{,}7 ; 2{,}6 ; 0 ; 0{,}1 ; 0) = 20{,}7\ \%$ **passed**

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}45 \cdot L = 0{,}45 \cdot 7920{,}00 = 3564{,}00$ mm

$C_{my} = 0.9$

$C_{mz} = \max(0{,}2 + 0{,}8 \cdot \alpha_{mz}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}741, 0{,}4) = 0{,}793 \geq 0{,}4$ Table B.3

$f_{yy} = \min(\lambda_y * - 0{,}2 ; 0{,}8) = \min(0{,}30 - 0{,}2 ; 0{,}8) = 0{,}101$

$f_{zz} = \max(\min(\lambda_z * - 0{,}2 ; 0{,}8) ; 0) = \max(\min(0{,}53 - 0{,}2 ; 0{,}8) ; 0) = 0{,}334$

$$k_{yy} = C_{my} \cdot \left(1 + f_{yy} \cdot \frac{\left|N_{Ed_9}\right|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}9 \cdot \left(1 + 0{,}101 \cdot \frac{|(-240791{,}50)|}{\frac{0{,}98 \cdot 1161439{,}27}{1}}\right) = 0{,}919$$

$k_{zy} = 0{,}6 \cdot k_{yy} = 0{,}6 \cdot 0{,}919 = 0{,}552$ Table Annex B.1

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}853 = 0{,}512$

$$k_{zz} = C_{mz} \cdot \left(1 + f_{zz} \cdot \frac{\left|N_{Ed_9}\right|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}793 \cdot \left(1 + 0{,}334 \cdot \frac{|(-240791{,}50)|}{\frac{0{,}91 \cdot 1161439{,}27}{1}}\right) = 0{,}853$$ Table Annex B.1

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y *^2}} ; 1\right) = 0{,}98 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z *^2}} ; 1\right) = 0{,}91 \quad (6.49)$$

$$\eta_{NMBuckl_1} = \frac{|N_{Ed_9}|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}} + k_{yy} \cdot \frac{|M_{y,Ed_9}|}{\frac{M_{pl,Rd,y}}{\gamma_{M1}}} + k_{yz} \cdot \frac{|M_{z,Ed_9}|}{\frac{M_{pl,Rd,z}}{\gamma_{M1}}} =$$

$$= \frac{|(-240791{,}50)|}{\frac{0{,}98 \cdot 1161439{,}27}{1}} + 0{,}919 \cdot \frac{|(-1861511{,}23)|}{\frac{64693441{,}50}{1}} + 0{,}512 \cdot \frac{|11507{,}24|}{\frac{42675873{,}60}{1}} = 23{,}9\ \% \quad (6.61)$$

$$\eta_{NMBuckl_2} = \frac{|N_{Ed_9}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}} + k_{zy} \cdot \frac{|M_{y,Ed_9}|}{\frac{M_{pl,Rd,y}}{\gamma_{M1}}} + k_{zz} \cdot \frac{|M_{z,Ed_9}|}{\frac{M_{pl,Rd,z}}{\gamma_{M1}}} =$$

$$= \frac{|(-240791{,}50)|}{\frac{0{,}91 \cdot 1161439{,}27}{1}} + 0{,}552 \cdot \frac{|(-1861511{,}23)|}{\frac{64693441{,}50}{1}} + 0{,}853 \cdot \frac{|11507{,}24|}{\frac{42675873{,}60}{1}} = 24{,}3\ \% \quad (6.62)$$

$\eta_{NMBuckl} = 24{,}3\ \%$ **passed**

4. Cross-section resistance to shear (y):

EN 1993-1-1: 6.2.6

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}83 \cdot L = 0{,}83 \cdot 7920{,}00 = 6600{,}00$ mm

$$A_{Vy} = \frac{A \cdot b}{b + h} = 1765{,}11\ \text{mm}^2$$

$$V_{pl,Rd,y} = \frac{A_{Vy} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{1765{,}11 \cdot 235{,}00}{\sqrt{3} \cdot 1} = 239484{,}74\ \text{N} \quad (6.18)$$

$$M_{x,Ed_1} = -77544{,}14\ \text{Nmm}$$

$$V_{pl,T,Rd,y} = \left(1 - \frac{\tau_{T,xy_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M1}}}\right) \cdot V_{pl,Rd,y} = \left(1 - \frac{0{,}29}{\frac{235{,}00}{\sqrt{3} \cdot 1}}\right) \cdot 239484{,}74 = 238964{,}19\ \text{N} \quad (6.28)$$

$$\eta_{V_y} = \frac{|V_{y,Ed_1}|}{V_{pl,T,Rd,y}} = \frac{|(-13{,}27)|}{238964{,}19} = 0\ \% \quad (6.17) \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}00 \cdot L = 1{,}00 \cdot 7920{,}00 = 7920{,}00$ mm

$a_{max} = 7{,}92$

$\eta_w = 1{,}2$ 5.2 (2) NOTE 2

$h_w = h - 2 \cdot t_f = 180{,}00 - 2 \cdot 10{,}00 = 160{,}00$ mm

No stiffener $\rightarrow k_\tau = 5{,}34$ (A.5)

$$\frac{h_w}{t_w} \le \frac{31 \cdot \varepsilon \cdot \sqrt{k_\tau}}{\eta_w} \rightarrow V_{b,Rd} = V_{pl,Rd,z} = 431072{,}53 = 431072{,}53\ \text{N} \quad (5.1\ (2))$$

$$\eta_{V_w} = \frac{\left|V_{z,Ed_{11}}\right|}{V_{b,Rd}} = \frac{|718,03|}{431072,53} = 0,2\ \%\quad (5.10)$$ **passed**

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0,17 \cdot L = 0,17 \cdot 7920,00 = 1320,00$ mm

$$M_{f,Rd} = (b + 2 \cdot b_2) \cdot t_f \cdot f_y \cdot (h - t_f) = (100,00 + 2 \cdot 0) \cdot 10,00 \cdot 235,00 \cdot (180,00 - 10,00) = 39950001,70\ \text{Nmm} = 39,95\ \text{kNm}$$

$$\rho_{Nf} = \frac{(1 - n)}{(1 - 0.5 \cdot a_w)} = \frac{(1 - 19,0)}{(1 - 0.5 \cdot 0,5)} = 0,9641$$

$$\left|M_{y,Ed_{11}}\right| \le M_{f,Rd} \cdot \rho_{Nf} \rightarrow \eta_{V_w MN} = \frac{\left|M_{y,Ed_{11}}\right|}{M_{pl,Rd,y}} = \frac{|(-1879877,57)|}{64693441,50} = 2,9\ \%\quad (7.1)$$ **passed**

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.

Critical combination: **[DL] {LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0,50 \cdot L = 0,50 \cdot 7920,00 = 3960,00$ mm

$$e_z = \left| e_{z,i} - e_{i,z} \cdot \left(1 - \frac{x}{L}\right) - e_{j,z} \cdot \frac{x}{L} + u_z \right| = \left| (-12,78) - (-10,31) \cdot \left(1 - \frac{3960,00}{7920,00}\right) - (-10,31) \cdot \frac{3960,00}{7920,00} + 0 \right| = 2,47\ \text{mm}$$

$$e_{z,Limit} = \frac{L}{300,0} = \frac{7920,00}{300,0} = 26,40\ \text{mm}$$

$$\eta_{e_z} = \frac{e_z}{e_{z,Limit}} = \frac{2,47}{26,40} = 9,4\ \%$$

$$\eta_{SLS} = \max\left(\eta_{e_z}\right) = \max(9,4) = 9,4\ \%$$ **passed**

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0,38 \cdot L = 0,38 \cdot 7920,00 = 2970,00$ mm

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{4942,29 \cdot 235,00}{1} = 1161439,27\ \text{N}\quad (6.10)$$

$$\eta_N = \frac{\left|N_{Ed_{11}}\right|}{N_{pl,Rd}} = \frac{|(-240791,50)|}{1161439,27} = 20,7\ \%\quad (6.9)$$ **passed**

9. Cross-section resistance to bending (yy):

EN 1993-1-1: 6.2.5

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}17 \cdot L = 0{,}17 \cdot 7920{,}00 = 1320{,}00$ mm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{275291{,}24 \cdot 235{,}00}{1} = 64693441{,}50 \text{ Nmm} = 64{,}69 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{\left|M_{y,Ed_{11}}\right|}{M_{pl,Rd,y}} = \frac{|(-1879877{,}57)|}{64693441{,}50} = 2{,}9\ \% \quad (6.12)$$ **passed**

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}00 \cdot L = 1{,}00 \cdot 7920{,}00 = 7920{,}00$ mm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{181599{,}46 \cdot 235{,}00}{1} = 42675873{,}60 \text{ Nmm} = 42{,}68 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{\left|M_{z,Ed_{11}}\right|}{M_{pl,Rd,z}} = \frac{|50337{,}05|}{42675873{,}60} = 0{,}1\ \% \quad (6.12)$$ **passed**

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6

Critical combination: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}00 \cdot L = 0{,}00 \cdot 7920{,}00 = 0$ mm

$$A_{V,z} = \frac{A \cdot h}{b + h} = 3177{,}19 \text{ mm}^2$$

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{3177{,}19 \cdot 235{,}00}{\sqrt{3} \cdot 1} = 431072{,}53 \text{ N} \quad (6.18)$$

$$M_{x,Ed_1} = 78995{,}51 \text{ Nmm}$$

$$V_{pl,T,Rd,z} = \left(1 - \frac{\tau_{T,xz_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M1}}}\right) \cdot V_{pl,Rd,z} = \left(1 - \frac{0{,}30}{\frac{235{,}00}{\sqrt{3} \cdot 1}}\right) \cdot 431072{,}53 = 430117{,}99 \text{ N} \quad (6.28)$$

$$\eta_{V_z} = \frac{\left|V_{y,Ed_1}\right|}{V_{pl,T,Rd,z}} = \frac{|13{,}07|}{430117{,}99} = 0{,}2\ \% \quad (6.17)$$ **passed**

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}33 \cdot L = 0{,}33 \cdot 7920{,}00 = 2640{,}00$ mm

$V_{z,Ed_1} = -407{,}79 \text{ N} \le V_{pl,Rd,z}/2 = 215536{,}26 \text{ N} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_1} = 0{,}61 \text{ N} \le V_{pl,Rd,y}/2 = 119742{,}37 \text{ N} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}33 \cdot L = 0{,}33 \cdot 7920{,}00 = 2640{,}00$ mm

$$n = \frac{\left|N_{Ed_1}\right|}{N_{pl,Rd}} = \frac{240791{,}50}{1161439{,}27} = 20{,}7\ \% \leq 25\%$$

$$\left|N_{Ed_1}\right| = 240791{,}50\ \mathrm{N} \geq N_{Rd,w}/2 = \frac{h_w \cdot t_w \cdot f_y}{2 \cdot \gamma_{M0}} = \frac{160{,}00 \cdot 10{,}00 \cdot 235{,}00}{2 \cdot 1} = 188000{,}00\ \mathrm{N}$$

$$a_f = \min\left(\frac{A - 2 \cdot h \cdot t_w}{A}\ ; 0{,}5\right) = \min\left(\frac{4942{,}29 - 2 \cdot 180{,}00 \cdot 10{,}00}{4942{,}29}\ ; 0{,}5\right) = 0{,}27$$

$$a_w = \min\left(\frac{A - 2 \cdot b \cdot t_f}{A}\ ; 0{,}5\right) = \min\left(\frac{4942{,}29 - 2 \cdot 100{,}00 \cdot 10{,}00}{4942{,}29}\ ; 0{,}5\right) = 0{,}5$$

$$\rho_{N_y} = \max\left(\frac{1 - n/100}{1 - 0{,}5 \cdot a_w}\ ; 0{,}01\right) = \max\left(\frac{1 - 20{,}7/100}{1 - 0{,}5 \cdot 0{,}5}\ ; 0{,}01\right) = 1{,}057$$

$$\rho_{N_z} = \max\left(\frac{1 - n/100}{1 - 0{,}5 \cdot a_w}\ ; 0{,}01\right) = \max\left(\frac{1 - 20{,}7/100}{1 - 0{,}5 \cdot 0{,}5}\ ; 0{,}01\right) = 1{,}057$$

$$M_{N,y,Rd} = \min\left(M_{y,V,Rd} \cdot \rho_{N_y}\ ; M_{y,V,Rd}\right) = \min\left(64693441{,}50 \cdot 1{,}057\ ; 64693441{,}50\right) = 64693441{,}50\ \mathrm{Nmm} = 64{,}69\ \mathrm{kNm}$$

$$M_{N,z,Rd} = \min\left(M_{z,V,Rd} \cdot \rho_{N_z}\ ; M_{z,V,Rd}\right) = \min\left(42675873{,}60 \cdot 1{,}057\ ; 42675873{,}60\right) = 42675873{,}60\ \mathrm{Nmm} = 42{,}68\ \mathrm{kNm}$$

$$\eta_{MN,1} = \frac{M_{y,Ed_1}}{M_{N,y,Rd}} = \frac{(-1671151{,}40)}{64693441{,}50} = 2{,}6\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_1}}{M_{N,z,Rd}} = \frac{12069{,}61}{42675873{,}60} = 0\ \%$$

$$\alpha_{MN} = \max\left(\min\left(\frac{1{,}66}{1 - 1{,}13 \cdot (n/100)^2}\ ; 6\right) ; 1\right) = \max\left(\min\left(\frac{1{,}66}{1 - 1{,}13 \cdot (20{,}7/100)^2}\ ; 6\right) ; 1\right) = 1{,}7$$

$$\beta_{MN} = \alpha_{MN} = 1{,}7 = 1{,}7$$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_1}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_1}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{(-1671151{,}40)}{64693441{,}50}\right)^{1{,}7} + \left(\frac{12069{,}61}{42675873{,}60}\right)^{1{,}7} = 0{,}2\ \% \quad (6.41)$$

$\eta_{MN} = \max\left(\eta_{MN,1}\ ; \eta_{MN,2}\ ; \eta_{MN,3}\ ; \eta_N\right) = \max\left(2{,}6\ ; 0\ ; 0{,}2\ ; 20{,}7\right) = 20{,}7\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **[1,35*0,85*DL] {1,5*LL}**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}45 \cdot L = 0{,}45 \cdot 7920{,}00 = 3564{,}00$ mm

$\alpha_{cr,Buck,y} = 53{,}39$

$N_{cr,y} = 12855726{,}00$ N

$K_y = 0{,}22$ Value calculated automatically.

$\alpha_{cr,Buck,z} = 16{,}9$

$N_{cr,z} = 4068392{,}10$ N

K_z = 0,25 Value calculated automatically.

$$L_{cr_y} = K_y \cdot L = 0{,}22 \cdot 7920{,}00 = 1763{,}72 \text{ mm}$$

$$L_{cr_z} = K_z \cdot L = 0{,}25 \cdot 7920{,}00 = 1964{,}96 \text{ mm}$$

Buckling curve about the y axis: *a* Table 6.2

$\rightarrow \alpha_y$ = 0,21 Table 6.1

Buckling curve about the z axis: *a* Table 6.2

$\rightarrow \alpha_z$ = 0,21 Table 6.1

$$\lambda_y{*} = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{4942{,}29 \cdot 235{,}00}{12855726{,}00}} = 0{,}30 \quad (6.50)$$

$$\lambda_z{*} = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{4942{,}29 \cdot 235{,}00}{4068392{,}10}} = 0{,}53 \quad (6.50)$$

$$\phi_y = \frac{1 + \alpha_y \cdot (\lambda_y{*} - 0{,}2) + \lambda_y{*}^2}{2} = \frac{1 + 0{,}21 \cdot (0{,}30 - 0{,}2) + 0{,}30^2}{2} = 0{,}5557$$

$$\phi_z = \frac{1 + \alpha_z \cdot (\lambda_z{*} - 0{,}2) + \lambda_z{*}^2}{2} = \frac{1 + 0{,}21 \cdot (0{,}53 - 0{,}2) + 0{,}53^2}{2} = 0{,}6778$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{*}^2}}\ ;1\right) = \min\left(\frac{1}{0{,}5557 + \sqrt{0{,}5557^2 - 0{,}30^2}}\ ;1\right) = 0{,}98 \quad (6.49)$$

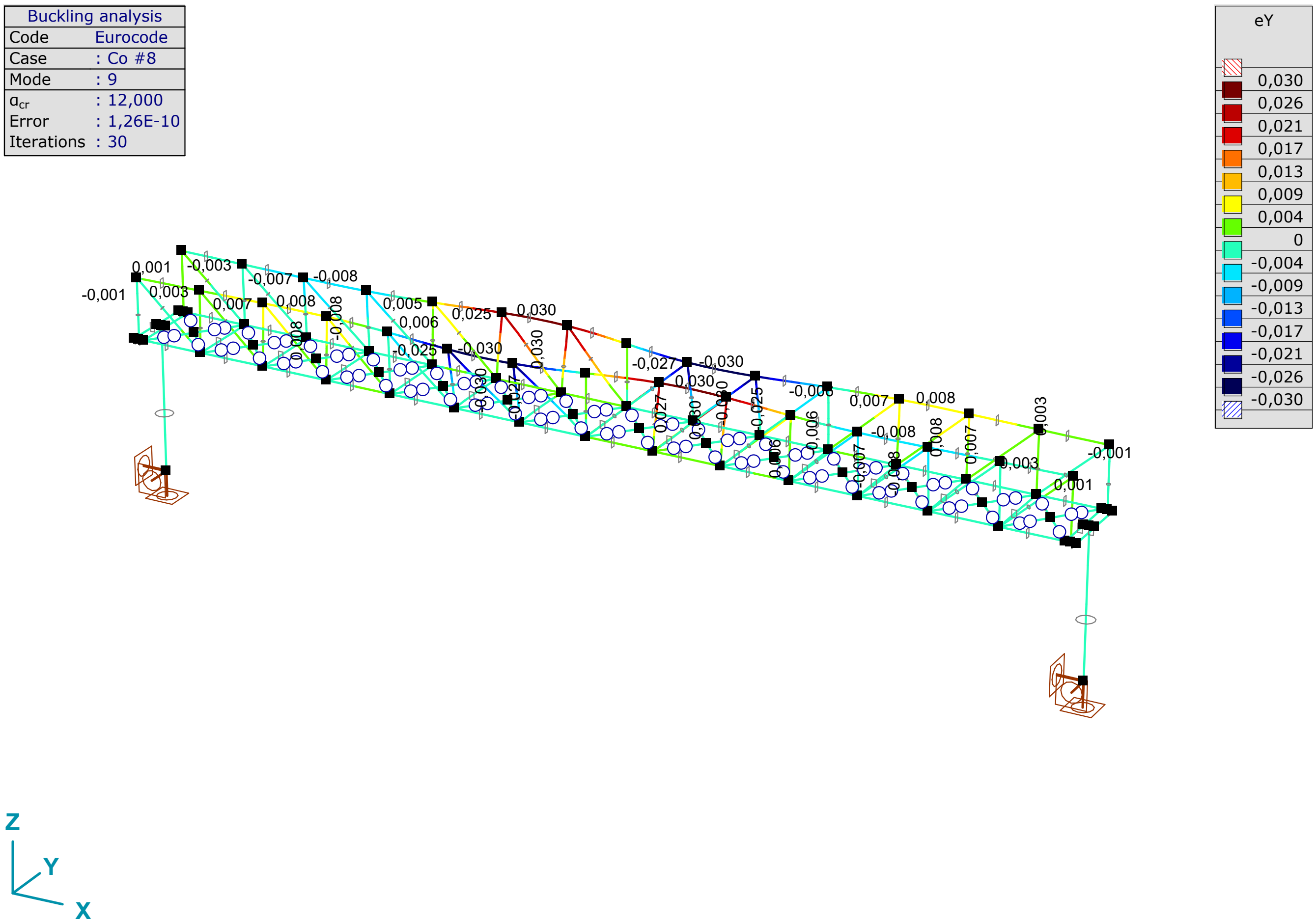
$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{*}^2}}\ ;1\right) = \min\left(\frac{1}{0{,}6778 + \sqrt{0{,}6778^2 - 0{,}53^2}}\ ;1\right) = 0{,}91 \quad (6.49)$$

$$\chi = \min\,(\chi_y\,;\chi_z) = \min\,(0{,}98\,;0{,}91) = 0{,}91 \le 1{,}0$$

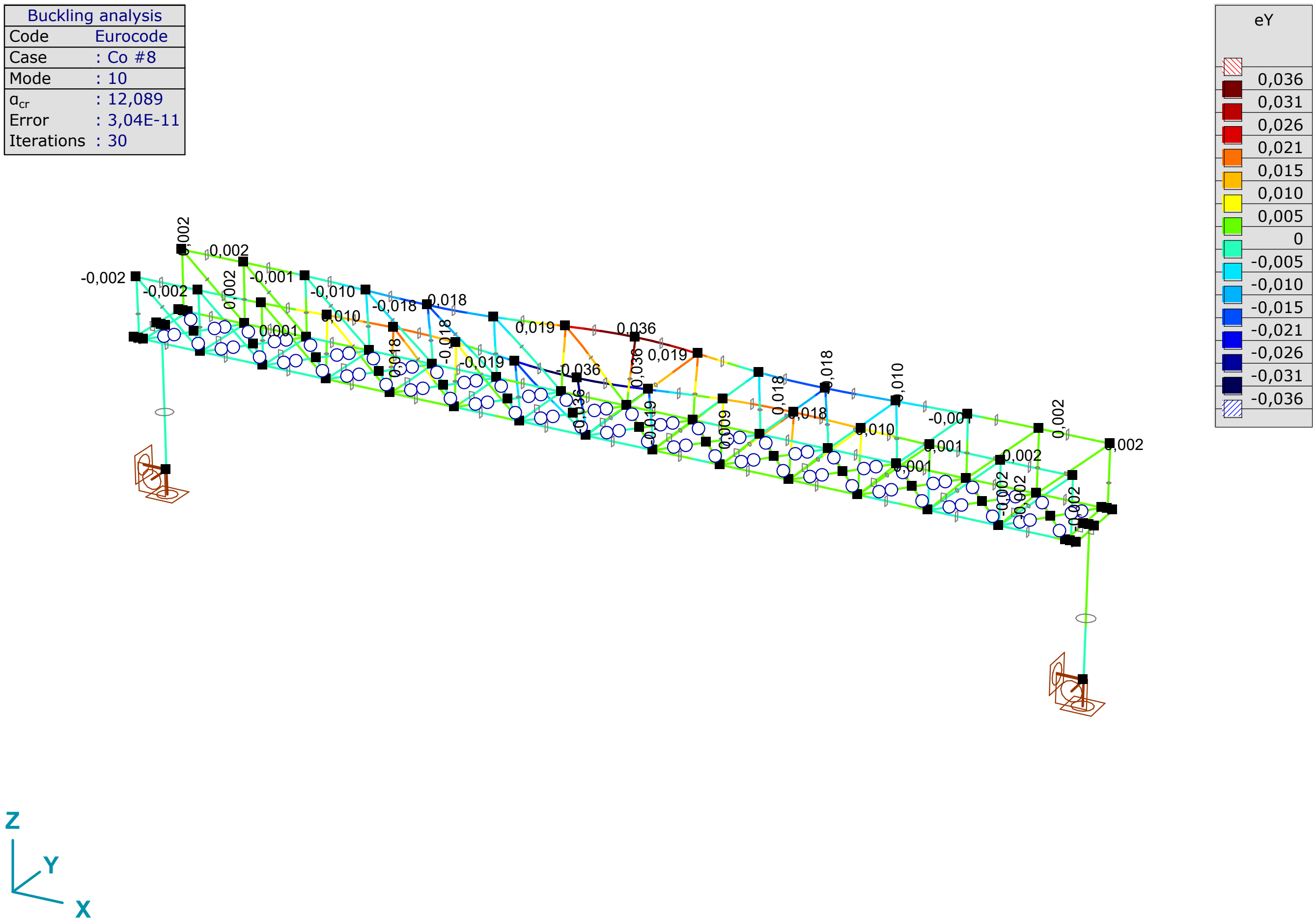
$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0{,}91 \cdot 4942{,}29 \cdot 235{,}00}{1} = 1060712{,}01 \text{ N} \quad (6.47)$$

$$\eta_{N_b} = \frac{|N_{Ed_9}|}{N_{b,Rd}} = \frac{|(-240791{,}50)|}{1060712{,}01} = 22{,}7\ \% \quad (6.46)$$ **passed**

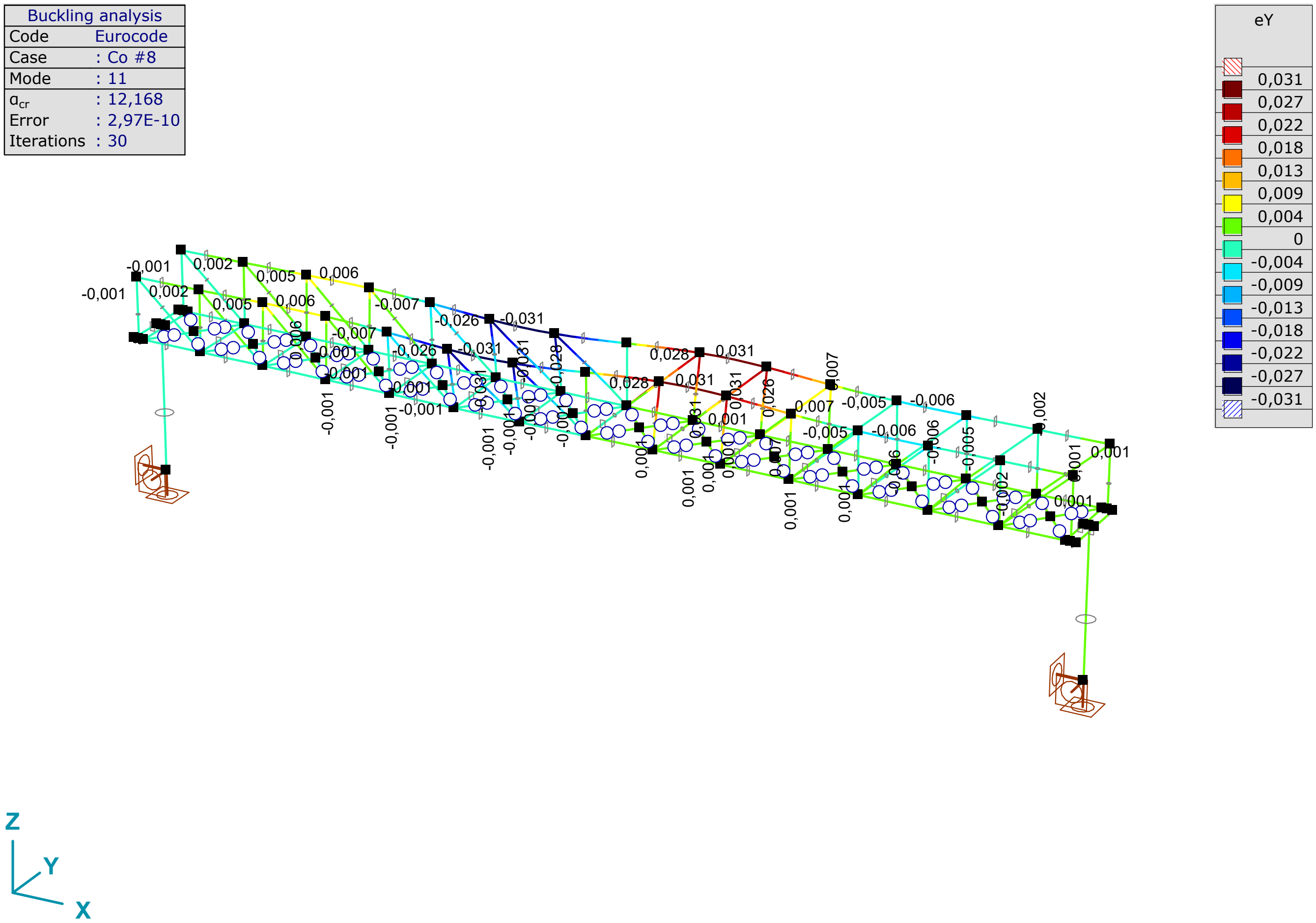
Eigenvalue buckling analysis



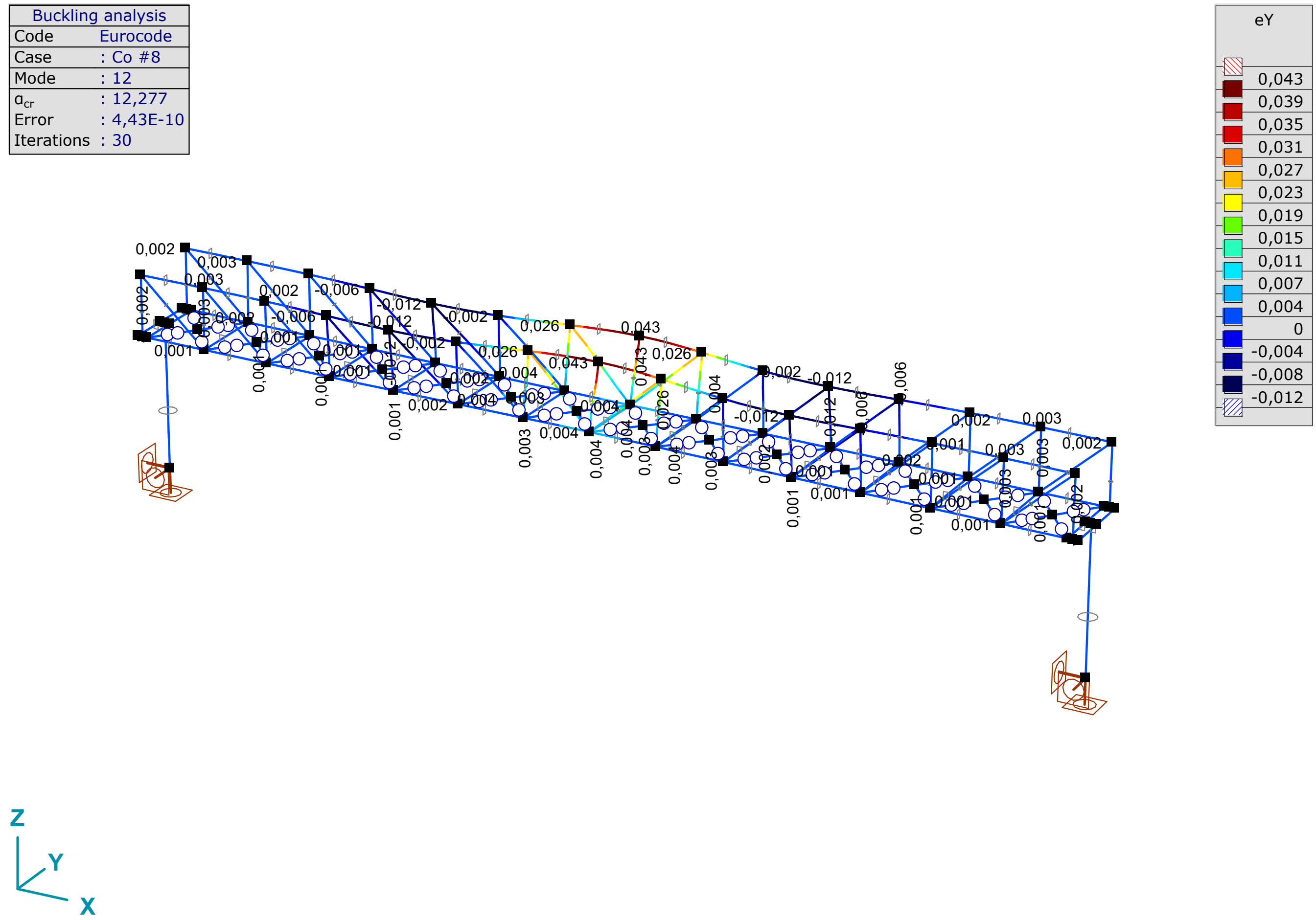
[Stab], Co #8 (ULS (a, b)) Mode 9 (12,000), eY, Isosurfaces 2D



[Stab], Co #8 (ULS (a, b)) Mode 10 (12,089), eY, Isosurfaces 2D



[Stab], Co #8 (ULS (a, b)) Mode 11 (12,168), eY, Isosurfaces 2D



[Stab], Co #8 (ULS (a, b)) Mode 12 (12,277), eY, Isosurfaces 2D

<u>Buckling analysis according to EN1993-1-1 is carried out based on bucking eigenvalues and corresponding non-dimensional slenderness. This independant analysis shows similar utilization of the compressed chord, difference between results is within acceptable tolerance.</u>

Buckling capacity based on critical load multiplier

According to EN 1993-1-1 Cl. 6.3.1.

$N_{Ed} := 241kN \qquad A := 50.97cm^2 \qquad F_y := 235MPa$

Critical load multiplier: $\alpha_{cr} := 12$

Critical load: $N_{cr} := N_{Ed} \cdot \alpha_{cr} = 2892 \cdot kN$

Imperfection factor of buckling curve: $\alpha_a := 0.21$

Non-dimensonal slenderness: $\lambda_{yI} := \sqrt{\frac{A \cdot F_y}{N_{cr}}}$

Reduction factor:

$$\phi_z := \frac{1 + \alpha_a \cdot (\lambda_{yI} - 0.2) + \lambda_{yI}^2}{2} = 0.754$$

$$\chi_z := \frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_{yI}^2}} = 0.873$$

Buckling resistance of compressed member: $N_{b.Rd} := \chi_z \cdot A \cdot F_y = 1045.3 kN$

$$\frac{N_{Ed}}{N_{b.Rd}} = 23.1 \cdot \%$$